SELES Spatial Timber Supply Model (STSM)

Assessing potential effects of climate change on natural disturbance and timber supply

An experiment in Morice Timber Supply Area

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Executive Summary

The SELES Spatial Timber Supply Model (STSM) supports explicit modelling of natural disturbance processes in a way compatible with assessing timber supply. A related memo describes how to set up and apply parameters for natural disturbance in the STSM. This memo presents a sensitivity analysis experiment using this process in Morice Timber Supply Area (TSA) to explore how potential impacts of climate change on landscape-scale natural disturbance may affect timber supply.

1 Introduction

Two projections of global atmospheric carbon (representative concentration pathways) have been used for many climate change analyses: RCP 4.5 and RCP 8.5. The former represents a possible pathway if carbon emissions peak around 2040 and then decline (i.e. mitigation at least as significant as in targets, such as the Paris Agreement). The latter represents rising emissions throughout the 21st century (i.e. no mitigation). These pathways represent reasonable bounds of a possible assessment range.

Many global circulation models (GCMs) have assessed carbon trajectories to attempt to project likely impacts on climate variables, usually at relatively coarse resolution (due to the global extent of the modeling), commonly with grid cells of dimension between 1 and 5 degrees latitude and longitude. These GCMs project a range of outcomes, due to the different factors included, different methods, and uncertainty. Given the range of results and the uncertainty about which one will turn out to be "correct", a reasonable approach is to use results that are averaged across multiple GCMs.

ClimateBC is a project developed at the Centre for Forest Conservation Genetics at the University of British Columbia[1] that uses historical weather data and GCM output to produce grids of the province for a number of climate variables that are scaled to 400m x 400m resolution, in particular average monthly temperature and precipitation.

We used ClimateBC outputs to provide a practical means of estimating changes in landscape-scale fire disturbance for a given study area (e.g. timber supply

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[1] http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/

area) that can be used in the SELES Spatial Timber Supply Model (STSM). Those methods were described in a separate memo[2].

This memo describes an experiment to apply those methods to assess potential timber supply impacts of climate change under three levels of salvage prioritization in Morice Timber Supply Area (TSA). The results indicate that future changes to natural disturbance caused by climate change can have significant near-term effects on timber supply.

2 Scenarios assessed

Three climate scenarios and three management scenarios were assessed, resulting in 9 scenarios in total.

The climate scenarios include historic normal from 1961-1990, and projections based on the RCP 4.5 and RCP 8.5 carbon trajectories. Fire parameters were developed using ClimateBC, based on BEC variant (except combining all sub-alpine variants, and combining the small area of MHmm with CWHws2). In addition to wildfire, disturbance agents for Mountain Pine Beetle (MPB), Spruce Bark Beetle (SBB) and Spruce 2-year Budworm (S2yB) were included (but changes due to climate change were only modelled for wildfire).

The management scenarios were all based on current management (2015 TSR base case), but with varying levels of salvage prioritization. The base level was derived from a calibration with the base natural disturbance that resulted in output non-recovered losses (NRLs) close to those used in previous TSRs. The “salvage priority” scenario prioritized salvage recovery before harvesting any live stands, while the in the “no salvage” scenario, no timber killed by natural disturbance was salvaged.

The resulting 9 scenarios are summarized in Table 1.

Table 1. Scenarios assessed by varying climate and salvage focus.

Scenario	Climate	Salvage
RCP0_BaseMgmt	Historic	Base (moderate)
RCP0_NoSalv	Historic	No salvage
RCP0_SalvPri	Historic	Salvage focus (priority)
RCP45_BaseMgmt	RCP 4.5	Base (moderate)

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[2] A. Fall. 2018, SELES Spatial Timber Supply Model (STSM): Parameterizing landscape-scape natural disturbance. Report to Forest Analysis Branch.

RCP45_NoSalv	RCP 4.5	No salvage
RCP45_SalvPri	RCP 4.5	Salvage focus (priority)
RCP85_BaseMgmt	RCP 8.5	Base (moderate)
RCP85_NoSalv	RCP 8.5	No salvage
RCP85_SalvPri	RCP 8.5	Salvage focus (priority)

2.1 Parameterizing natural disturbance

The natural analysis units were created as an overlay of merged BEC variants used for wildfire, and species type (pine, spruce and other, as used for MPB, SBB and S2yB). There are 8 merged BEC variants (sub-alpine, CWHws2/MHmm, ESSFmc, ESSFmk, ESSFmv3, SBSdk, SBSmc2 and SBSwk3), resulting in 24 natural analysis units.

Parameters for wildfire were derived using the approach described in the companion parameterizing landscape-scape natural disturbance memo[2], using fire history summaries for the entire province by BEC variant. The historical fire database was used to calculate the total area burned and the distribution of fire sizes by BEC variant, from which parameters for fire cycle (rotation) and mean fire size were developed. The fire size distribution was adequately represented as a negative exponential distribution.

The fire rotations and mean fires size by BEC variant are shown in Table 2.

Table 2. Rotation and mean patch size parameters for wildfire disturbance.

BEC	Rotation	Mean fire size
ATp	2422	26
CWHws2	3792	115
ESSFmc	1357	615
ESSFmk	3692	352
ESSFmv3	1207	945
SBSdk	303	290
SBSmc2	531	808
SBSwk3	1415	619

The proportion of merchantable volume lost immediately due to fire was set at 10%, based on calibration using base management and climate compared NRL inputs used for previous TSRs (i.e. so that the output NRLs from the model were similar to the input NRLs used in previous TSRs).

Shelf life was set at 10 years for all fire zones. Stand preference was specified as random (i.e. wildfires initiated randomly, independent of stand age). Fire size distribution was set as negative exponential, based on the distribution of historic fire sizes.

Parameters for MPB, SBB and S2yB were based on previous TSR reports and general information on these insects, although parameters for future outbreaks are uncertain[3].

The rotations and disturbance patch size for MPB, SBB and S2yB were as follows, and were derived via calibration with previous TSRs.

Table 3. Rotation and mean patch size parameters for insect disturbance agents.

Agent	Rotation	Mean patch size
MPB	400	100 ha (std. dev. 20 ha)
SBB	300	20 ha (std. dev. 5 ha)
S2yB	1000	15 (10-20 ha)

The proportion of merchantable volume lost immediately due to insects was set at 0%, assuming that the agent itself does not degrade merchantable wood, and that degradation occurs as dead trees decay.

Shelf life was set at 15 years for all insects. Stand preference was specified as oldest-first for MPB and SBB, with all stands older than 150 years assigned equal preference (i.e. assuming the MPB and SBB preferably attack larger older trees) and random for S2yB. Infestation patch size distribution was set as normal for MPB and SBB with mean of 100 ha and 20 ha, respectively, and standard deviation of 20 ha and 5 ha, respectively, based on general historic patterns. Infestation patch size distribution was set as uniform for S2yB, with a range of 10 to 20 ha.

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[3] https://www.for.gov.bc.ca/rsi/foresthealth/PDF/MPBpamphlet.pdf

https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-health/bark-beetles/bark_beetle_management_guidebook.pdf

To keep the experiment simple and more controlled for timber supply assessment, no variability was applied to natural disturbance rotations. This means that the proportion of area disturbed each year by each agent was exactly 1/rotation (e.g. for a rotation of 100 years, this would mean 1% of the potentially affected forest per year). In the historic climate scenario, this resulted in a constant area disturbed per year, and in the climate change scenarios, the area changed over time as rotation changed. Note that a fixed area disturbed does not necessarily mean a fixed amount of merchantable volume disturbed, since the exact areas disturbed were stochastic.

2.2 Calibration with previous TSRs

The 2015 TSR AAC Rationale[4] for Morice TSA describes the following NRLs:

- Wildfire: 60,686 m^3/year
- MPB (future): 9,000 m^3/year NRL from 20,272 m^3 annual kill
- SBB: 20,946 m^3/year
- S2yB: 4,595 m^3/year

The wildfire disturbance levels were based on historic fires from 1992 to 2012, which affected about 13,500 ha. The insect disturbance levels were based on aerial overview surveys from 1999 to 2012.

The base case scenario from the 2015 TSR, but with natural disturbance modelled using historic climate and NRLs as outputs, was run several times to adjust disturbance agent parameters (shelf life for fire and rotation for insects) to more closely match the 2015 TSR NRL input values. Using the parameters described in the previous section, emergent NRLs from modelled years 40-250 were as follows:

- Wildfire: 66,625 m^3/year
- MPB (future): 22,188 m^3/year
- SBB: 17,856 m^3/year
- S2yB: 6,283 m^3/year

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[4] https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/tsr-annual-allowable-cut/morice_tsa_rationale.pdf

This resulted in about 112,953 m^3/year emergent NRL from modelled years 40-250 (the first few time steps were omitted to take into account the first period of salvage from the past MPB infestation, and to allow shelf life to pass for the model to start recording output NRL). This is intermediate between the NRLs from the 2015 TSR analysis (95,227 m^3/year) and the NRLs from the pre-MPB outbreak 2002 TSR2 analysis (181,859 m^3/year for the first 50 years, and 104,572 m^3/year thereafter).

2.3 Dynamic changes to wildfire rotation due to climate change

We used mean monthly temperature outputs from ClimateBC at years 2025, 2055 and 2085 for the RCP 4.5 and RCP 8.5 trajectories, based on an ensemble of 15 GCMs, as well as the 1961-1990 normal climate period, to compute the proportion of cells within each BEC variant that were warmer than 10º C.

That is, we summed across all months, in each BEC variant, the number of grid cells with mean daily temperature $\geq$ 10 degrees C, which we call $sumFireWeather_{scn}$, where *scn* is a given climate scenario (i.e. normal period or one of the projected periods). The rotation scale factor was then computed as:

$$sumFireWeather_{prjScn} \,/\, sumFireWeather_{normalScn}$$

where *normalScn* is the normal period scenario, and *prjScn* is a given year in a given projection scenario (e.g. RCP8.5 at 2085).

The inverse of this value can be used to dynamically vary the fire rotation (e.g. a scale factor of 2, representing a doubling of fire disturbance, means that fire rotation is shortened by ½). This relatively simple method to estimate expected changes to fire rotation combines the effects of changes to fire season length and changes to fire season intensity.

Scale factors were computed for each climate scenario and each projected time period (2025, 2055 and 2085), and then applied to the 1961-90 fire rotations, with the results shown in the following table. Scale factors for other years were interpolated (but remained constant after 2085).

Table 4. Adjusted wildfire rotations at 2025, 2055 and 2085 under the RCP 4.5 and RCP 8.5 climate scenarios.

Climate scenario	**Normal Period (1961-1990)**	**RCP 4.5 (15 GCM ensemble)**			**RCP 8.5 (15 GCM ensemble)**		
BEC variant / Time period	**start**	**2025**	**2055**	**2085**	**2025**	**2055**	**2085**
ATp	2422	1461	1182	994	1441	959	785
CWHws2	3792	2769	2185	2038	2722	2021	1756
ESSFmc	1357	970	809	725	958	706	571
ESSFmk	3692	2645	2008	1891	2606	1881	1581
ESSFmv3	1207	824	776	721	818	695	472
SBSdk	303	240	200	184	231	183	181
SBCmc2	531	424	337	305	415	301	268
SBSwk3	1415	1226	962	808	1215	790	737

2.4 Management scenarios

The base management scenario applied a mixed focus on salvage and live tree harvest. It applied a preference to volume relative to the volume at the age of the maximum mean annual increment (culmination age), with an added weight to merchantable salvage volume. More specifically, the preference adjustment factor is:

$$(\text{Live m}^3/\text{ha} + 10^*\text{Salvagable m}^3/\text{ha}) / \text{culmination age m}^3/\text{ha}$$

For a live stand, this factor is 1 when the stand age is at culmination age, less than 1 (less preferable) at ages younger than culmination age, and increasingly greater than 1 (more preferable) as the stand ages beyond culmination age. Potential salvage volume is at most the live volume at the time that the stand was disturbed, and the multiplier of 10 increases preference for stands with salvage (depending on the ages of other available stands on the landscape).

The no salvage management scenario is limited to harvesting live stands, and excludes all killed volume from the timber supply. Since minimum harvest age is much longer than shelf life, this is implemented by allowing harvest only in live stands (older than min. harvest age) and not in stands with salvage (which will, by definition, be younger than min. harvest age).

The salvage priority management scenario adds a priority on salvage. This priority is processed before the main priority (which is the same as in the base management). The salvage priority is allowed to harvest up to 100% of the harvest target, can only log in stands with some salvage and applies a "highest salvage volume first" rule. That is, it will harvest all accessible salvage that meets minimum volume criteria before harvesting any live stands.

3 Results

Figure 1 and Table 5 show the resulting harvest flows from the analysis. The two main drivers of differences are (i) whether or not climate change is modelled (with relatively minor differences between RCP 4.5 and RCP 8.5); and whether or not there is salvage in the management regime (with relatively minor differences between base salvage and salvage priority). Including climate change effects shortened fire rotations, which led to a timber supply impact of about 100,000 m^3. In addition, if salvage was ignored (i.e. all disturbed volume becomes NRL), there was an additional negative impact of about 100,000 m^3. Impacts affected timber supply immediately after the 1st period[5].

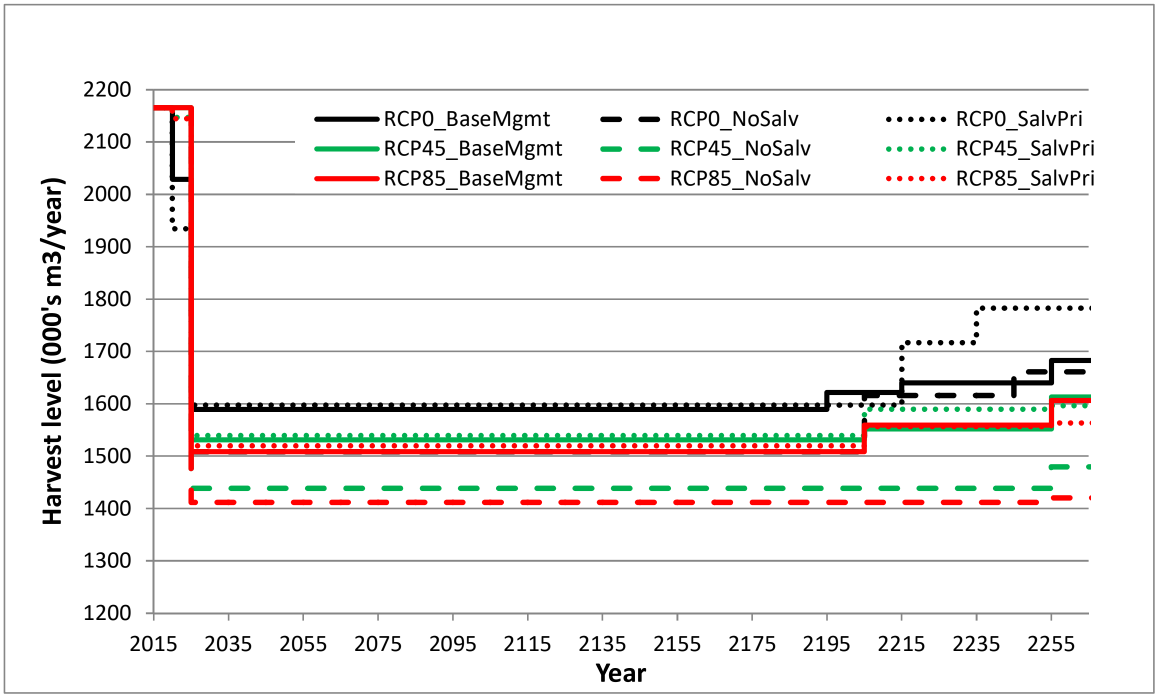

Figure 1. Harvest flows of experiment scenarios. Note y-origin is at 1,200,000 m^3.

Table 5. Harvest flow results from 9 experiment scenarios (values in '000s of m^3).

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[5] Note that the 1st period focuses on modelling salvage from the recent MPB outbreak, as in the 2015 TSR.

Climate	Historic climate (RCP0)			RCP4.5			RCP8.5		
Salvage Mgmt / Year	Base Mgmt	No Salvage	Salvage Priority	Base Mgmt	No Salvage	Salvage Priority	Base Mgmt	No Salvage	Salvage Priority
2015	2,165	2,165	2,165	2,165	2,165	2,165	2,165	2,165	2,165
2020	2,029	2,165	1,934	2,165	2,165	2,147	2,165	2,165	2,145
2025	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2035	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2045	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2055	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2065	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2075	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2085	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2095	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2105	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2115	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2125	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2135	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2145	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2155	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2165	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2175	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2185	1,589	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2195	1,622	1,508	1,597	1,531	1,438	1,539	1,508	1,411	1,520
2205	1,622	1,616	1,597	1,552	1,438	1,589	1,559	1,411	1,556
2215	1,640	1,616	1,717	1,552	1,438	1,589	1,559	1,411	1,556
2225	1,640	1,616	1,717	1,552	1,438	1,589	1,559	1,411	1,556
2235	1,640	1,616	1,783	1,552	1,438	1,589	1,559	1,411	1,556
2245	1,640	1,661	1,783	1,552	1,438	1,589	1,559	1,411	1,556
2255	1,683	1,661	1,783	1,613	1,479	1,596	1,606	1,420	1,563
2265	1,683	1,661	1,783	1,613	1,479	1,596	1,606	1,420	1,563